REMR Technical Note GT-RE-1.3

ROCK EROSION IN SPILLWAY CHANNELS

PURPOSE: To report on research using a recirculating tilting flume and stratified, simulated earth materials (gravel-gelatin mixtures) to determine the influence of stratigraphic variation on the initiation and rate of knickpoint erosion in unlined emergency spillway channels which indicates that the maximum rate of headward erosion does not necessarily correspond to the period of maximum discharge.

APPLICATION: Prototype modeling of the effect of stratigraphic variation on the initiation and rate of knickpoint erosion in unlined emergency spillway discharge channels.

ADVANTAGES: Enhanced prediction of channel response to emergency spillway overflow.

EXPERIMENTAL RESULTS: Headward erosion of a knickpoint is generally controlled by the following interrelated factors or conditions: (a) stratigraphy of the rocks forming the knickpoint or waterfall, (b) the ratio of the depth of water (Y) over the waterfall to the height of the waterfall (Z), (c) tailwater conditions, (d) venting condition of the waterfall, and (e) location or position on the hydrograph describing the discharge event. These factors and conditions are described below:

a. Headward erosion is enhanced by the occurrence of interstratified layers of hard and soft (erodible) rocks.

b. In a typical drop structure, maximum dissipation of energy occurs when the ratio, Y/Z , is less than approximately 1/8 since the distance from the base of the falls at which the water strikes is proportional to Z . Maximum dissipation of energy in a drop structure would be similar to maximum energy for erosion at a waterfall. The height, Z , is dependent upon the stratigraphic thickness(es) (Figure 1).

c. Maximum erosion occurs when tailwater height is minimized.

d. The discharge over a waterfall produces a "reverse roller" (Q2 in Figures 1 and 2), which is the principal mechanism causing erosion. The air pocket behind the waterfall may be either vented (Figure 1) and at atmospheric pressure or unvented (Figure 2) and at a pressure less than atmospheric. When conditions are unvented, the low pressure in the air pocket draws the reverse roller against the face, accelerating erosion there. The flume experiments demonstrated that an initially vented waterfall became unvented during discharge increases when the air pocket is replaced by water. Also, when

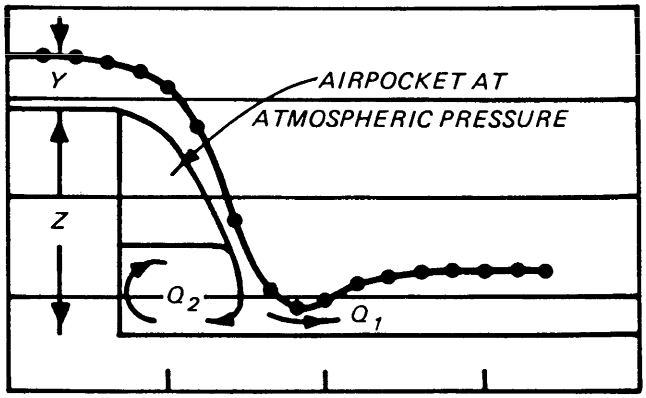

Figure 1. Geometry of vented knickpoint

discharge decreased, a low-pressure zone developed behind the waterfall, entraining air bubbles that coalesce to form an air pocket. These pressure differences drew the reverse roller onto the face of the waterfall, producing erosion. These effects were found to be true even when the ratio, Y/Z , was greater than 1/8.

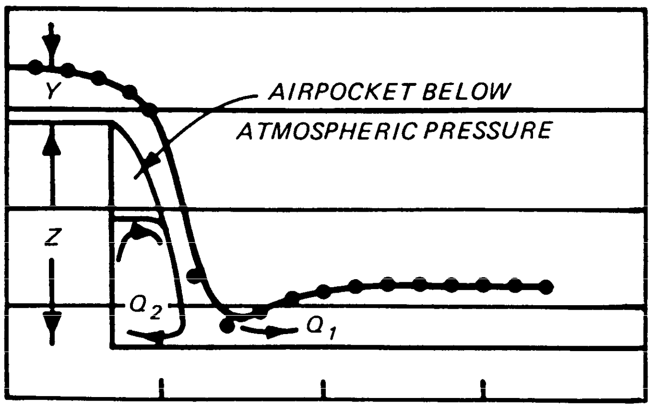

Figure 2. Geometry of an unvented knickpoint

e. Using hypothetical flood hydrographs (analogous to emergency spillway discharge events), these findings indicated that certain erosion "windows" occurred as a result of stratigraphy and its influence on knickpoint height. Figure 3 illustrates the scenario observed in the flume experiments for a vented waterfall in which Y/Z is less than 1/8. As velocity and discharge increased rapidly, the waterfall moved further from the face, and erosion ceased. However, a slow decrease in discharge resulted in a resumption of knickpoint erosion. The second phase of the erosional activity was observed to be more pronounced than the first because of the additional time involved. In another scenario, the knickpoint was unvented and Y/Z was greater than 1/8. In this case, the height of the knickpoint did not allow the reverse roller to come into close proximity to the knickpoint face during the period of increasing discharge. During the period of decreasing discharge, the aforementioned pressure differential allowed the reverse roller to be drawn in toward the knickpoint face, causing a window of erosion to occur, as shown in Figure 4.

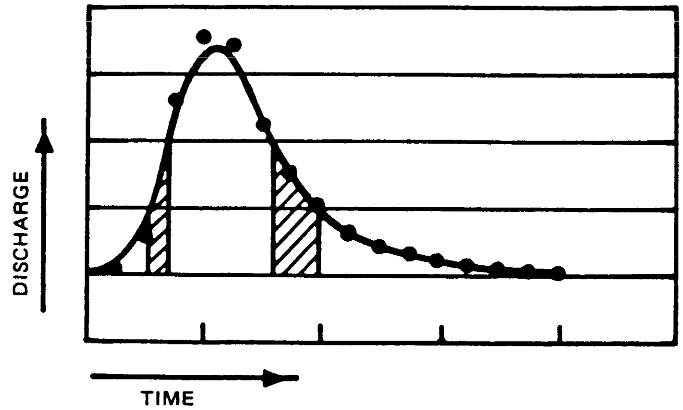

Figure 3. Erosion at a vented knickpoint

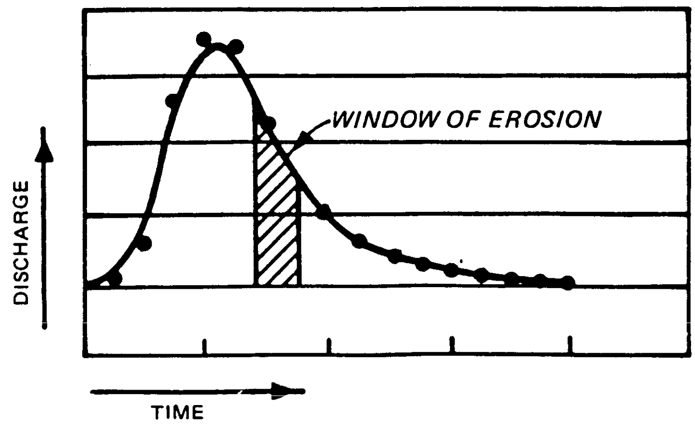

Figure 4. Erosion at an unvented knickpoint

f. The results of these flume experiments to date indicate that the severity of erosion is apparently dependent on the erodibility and thickness of the strata forming the waterfall, venting, and the hydrology of the overflow event. The tabulation below summarizes the erosion potential under different conditions:

Ratio Y/Z	Venting	Point on Hydrograph	
		Rising Limb	Falling Limb
<1/8	Yes	Severe erosion	Severe erosion
>1/8	Yes	Normal erosion	Normal erosion
1/8 ratio not critical	No	Most severe erosion	Most severe erosion

REFERENCES: a. Cameron, Christopher P., Cato, Kerry D., McAneny, Colin C., and May, James H. 1986. "Geotechnical Aspects of Rock Erosion in Emergency Spillway Channels; Report 1," Technical Report REMR-GT-3, US Army Engineer Waterways Experiment Station, Vicksburg, MS.

b. Cameron, Christopher P., Patrick, David M., Cato, Kerry D., and May, James H. "Geotechnical Aspects of Rock Erosion in Emergency Spillways; Report 2, Analysis of Field and Laboratory Data" (in preparation), Technical Report REMR-GT-3, US Army Engineer Waterways Experiment Station, Vicksburg, Miss.

c. May, James H. "Geotechnical Aspects of Rock Erosion in Emergency Spillways; Report 4, Flume Studies of Knickpoint Erosion Channels" (in preparation), Technical Report REMR-GT-3, US Army Engineer Waterways Experiment Station, Vicksburg, MS.